Towards a THz room-temperature integrated parametric source

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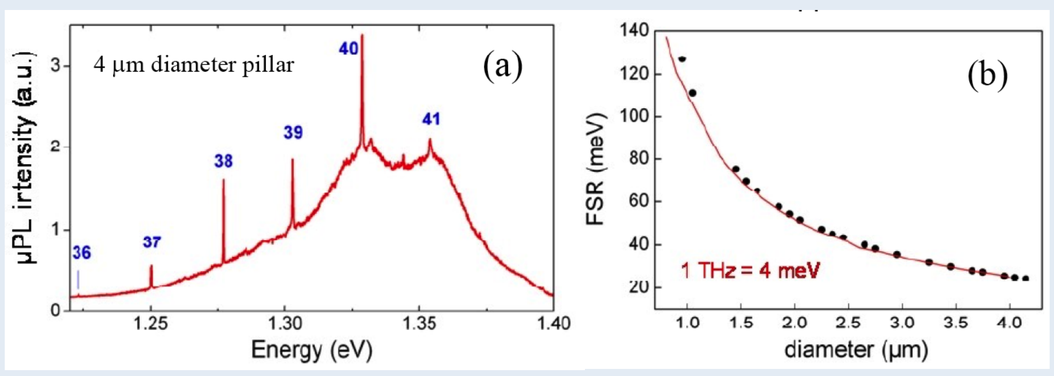
MOTIVATION

We aim at demonstrating a radically new continuous-wave, electrically pumped terahertz emitter. Compared to existing THz sources, this source will bring together several crucial advantages that are far from being simultaneously available in any existing source today: compact size, room-temperature operation, output power above 1 μW, custom emission frequency from 2.4 to 6 THz, spectral purity, feasibility of multi-spectral array of emitters, and perspective of coherent detection schemes.

FORMER OBSERVATION (Grenoble, 2007)

Photo-luminescence of GaAs/AlAs micropillars containing InAs quantum dots (QDs) is dominated by one family of horizontally polarized, near-IR, high-Q whispering gallery modes (WGMs). [1]

- nanofabrication by MBE, e-beam lithography and RIE
- high Q-factor WGMs (diam. 4μm, $Q>10^4$)
- stable multi-mode lasing
- no gain competition (QD active medium)
- better heat-sinking than in microdisks
- THz free spectral range (FSR) for sufficiently large diameters



WGMs in a micropillar, from Ref. [1]: measured spectrum (a) and FSR (b).

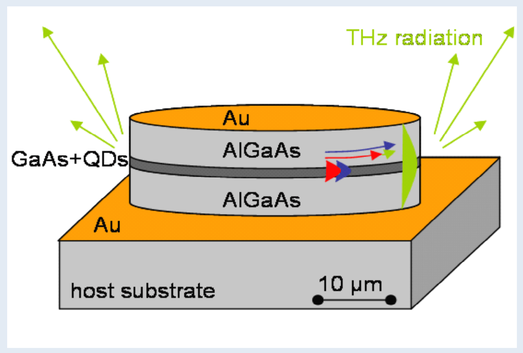
CONTEXT

In 2008 Capasso's group at Harvard has proposed a THz source based on DFG in a dual-λ mid-IR QCL. [2] Due to heavy doping, its performance is limited by free-carrier absorption (FCA) in the THz, and it can only emit pulses of a few hundreds of nW at 300 K.

THE IDEA BEHIND THE PROJECT (Paris, 2008)

DFG in an AlGaAs active whispering gallery resonator (WGR). [3] Vertical confinement of the optical field provided by dielectric or plasmon-enhanced guiding. In the horizontal plane, guidance granted by the bent semiconductor/air interface. Performance measured in terms of Q factor and FSR.

Two phase-matching schemes for THz DFG in WGRs fabricated on (100)-GaAs: 1) anomalous dispersion related to the phonon absorption band; 2) QPM associated to the azimuthal modulation of the effective $\chi^{(2)}$. [4]



The TREASURE device

THE TREASURE PROJECT (May 2010 – April 2013)

During the first year of the project, we have:

1. demonstrated lasing in QD WGRs, in the CW regime at 100 K, under optical pumping [5], as well as electrical pumping at 10 K; [6]
2. progressed in the modeling of the laser heterostructure (composition profile and doping), the linear and nonlinear behavior of near-IR and THz WGMs, as well as the radiating features of the THz emitter; [7]
3. fabricated and tested the experimental setup for the linear and nonlinear optical characterization of passive and active WGRs. [8, 9]

CONCLUSION AND PERSPECTIVES

Most relevant result of TREASURE's first year:

- Demonstration of lasing in QD WGRs under electrical pumping.

Main issues in the next semester:

- Confirm via fully vectorial FDTD the effective-index predictions of THz DFG between 2.4 and 6 THz, in the microwatt range.
- Characterize the first WGR samples.
- Achieve the lasing of optically pumped WGRs at 300K.
- Achieve low-threshold lasing in electrically-pumped WGRs.

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TREASURE

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